Age and Growth of King Mackerel, *Scomberomorus cavalla*, From the U.S. Gulf of Mexico

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Introduction

The importance of king mackerel, *Scomberomorus cavalla*, to recreational and commercial fisheries along the southeastern Atlantic and Gulf of Mexico coasts of the United States has been thoroughly documented (Manooch et al., 1978; Manooch, 1979; Collette and Russo, 1984). Unfortunately, the importance of this coastal migratory species and the need for large-scale, regionally coordinated research has not been recognized until recently[1,2]. Manooch et al. (1978) provided an annotated bibliography of four western Atlantic scombrids and concluded that there was missing or incomplete knowledge concerning recreational catch and effort, migratory patterns, stock identity, and large-scale life history studies. Fishermen, scientists, and fishery managers still recognize these as priority research areas critical to the management of king mackerel stocks which are judged to be heavily exploited along both coasts. The National Marine Fisheries Service, regional universities, and state conservation agencies have responded to this need and have initiated extensive research efforts under the Marine Fisheries Initiative (MARFIN) Program.

Knowledge of age and growth is a life history aspect which is fundamental to resource management. Resulting data may be used to evaluate the impacts of fishing on the stocks or determine how they respond to different levels and strategies of fishing. Most studies on the age and growth of king mackerel have shared the deficiency of being restricted by either time or space (Manooch et al. 1978), however, Johnson et al. (1983) provided the most comprehensive geographic coverage.

Herein we report on an independent study on the Gulf of Mexico king mackerel management unit. The objectives were to: 1) Determine if rings on king mackerel otoliths were formed annually, 2) document the age and growth of the species in the Gulf of Mexico, 3) use sex specific otolith radii-fish length regressions to back-calculate fish length-at-age for the sexes, 4) derive theoretical growth equations for each sex, 5) generate more current age-length keys, and 6) estimate mortality from catch curves using sex specific age-length keys.

Materials and Methods

King mackerel were sampled from recreational and commercial fisheries operating in the Gulf of Mexico from Key West, Fla., to the Yucatan Peninsula, Mex., from 1980 to 1985. Saggital otoliths from 1,098 fish were used in the study, and most were removed from king mackerel sampled off Key West, northwest Florida, and Texas (Table 1). Fork lengths (mm) were recorded for all fish,

[1]Fishery management plan and environmental impact statement for coastal migratory pelagic resources (mackerels) in the Gulf of Mexico and South Atlantic region, final amendment 1. 1985. Gulf of Mexico Fishery Management Council, Tampa, Fla., and South Atlantic Fishery Management Council, Charleston, S.C.

[2]A State/Federal plan to fill information needs for management of king mackerel resources in the southeastern United States. [Draft]. Gulf of Mexico Fishery Management Council, Gulf States Marine Fisheries Commission and National Marine Fisheries Service, King Mackerel Research Planning Meeting, New Orleans, January 6-7, 1986.

ABSTRACT—Whole otoliths of 1,098 king mackerel, Scomberomorus cavalla, *410-1,802 mm fork length (FL) were examined. The fish were sampled from recreational and commercial fisheries operating in the Gulf of Mexico from Key West, Fl., to the Yucatan Peninsula, Mex., from 1980 through 1985. Most fish were collected off Key West, northwest Florida, and Texas. The oldest fish was 14 years old and measured 1,802 mm FL. Rings formed on most otoliths during the late winter through spring (February-May) and are thus considered to be true annual marks. Back-calculated mean lengths of 947 fish ranged from 420 mm at age 1 to 1,269 mm FL at age 14. Females live longer and attain larger sizes than males. The von Bertalanffy growth equation for both sexes combined is* $L_t = 1{,}478\ (1 - e^{-0.1154(t + 2.3599)})$, *where* L = *fork length and* t = *years. The equation for females is* $L_t = 1{,}417\ (1 - e^{-0.1360(t + 1.9754)})$, *and for males is* $L_t = 1{,}113\ (1 - e^{-0.2080(t + 1.4808)})$. *King mackerel are fully recruited to the gillnet and purse-seine fisheries of south Florida at age 2, to the recreational hook and line fishery off northwest Florida at ages 1 or 2, and to the Texs recreational hook and line fishery at ages 2 or 3. Total instantaneous mortality estimates* (Z) *ranged 0.53-0.82 for south Florida gillnet caught mackerel, 0.46-1.01 for northwest Florida hook and line fish, and 0.29-0.47 for fish caught by recreational hook and line off Texas. Mortality estimates were always lower for females than males for any area, gear, or month comparisons.*

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Table 1.—Areas where king mackerel were collected.

Collection area	No. of fish	Collection area	No. of fish
S. Florida (Keys)	376	Mississippi Delta	4
N.W. Florida	506	Mexico	11
Alabama	1	Gulf of Mexico	3
Mississippi	5	Total	1,098
Lousiana	10		
Texas	182		

and weight and sex were determined when time and conditions permitted.

Whole otoliths were immersed in clove oil, placed in a black-bottom watchglass illuminated by reflected light, and examined at 50X through a dissecting microscope. After counting the number of rings, we measured distances from the otolith core to the distal edge of each ring, from the core to the otolith edge, and from the last ring to the otolith edge. We used the same plane of measurement as Johnson et al. (1983). We also prepared transverse sections about 0.7 mm thick using a Beuler[3] low-speed jewelers' saw from some otoliths embedded in black parafin. No annular measurements were made on otolith sections because the equidistant spacing of the outer rings on older fish may suggest a decoupling or changing relationship between otolith growth and fish growth in old age, thus making annular measurement of questionable use for back calculation of size-at-age (C.B. Grimes, personal commun.).

The time of ring formation was evaluated in two ways: 1) Plotting the distance from the last ring to the otolith edge by month, and 2) plotting the frequency of otoliths with marginal rings by month. In addition, we plotted core-to-ring measurements to determine if ring formation was consistent for different age groups.

To determine the relationship of the size of the otolith (OR) to the size of the fish (FL), we used least square regressions of power curves: $FL = aOR^b$. Equations were developed for both sexes combined, as well as for males and females separately using a stratified sample of 210 otoliths. All otoliths samples were ordered by fish length, from smallest to largest, and a random sample was drawn from each 100 mm interval until the 210 samples had been selected. This set was used to derive the overall equation, and when sex was assigned to each sample, then two subsets were identified, one for each sex (N = 122 for females, N = 88 for males). Once the relationships were obtained, fish sizes at earlier ages were back-calculated (Everhart et al., 1975; Ricker, 1975).

The von Bertalanffy growth equation $L_t = L_\infty \ (1 - e^{-K(t - t_0)})$ was fitted to back-calculated lengths using the Marquardt nonlinear iterative procedure (SAS Institute, 1982) to obtain estimates for L_∞, K, t_0, and their respective asymtotic 95 percent confidence intervals. Overall and sex specific back-calculated data were used to derive growth equations for both sexes combined (overall), for all females, for all males, and for females aged 1-10 years, and for males aged 1-9 years. The latter two groups enabled comparison of our results with Johnson et al. (1983) who fitted growth equations using the same ages.

We estimated total annual mortality by analyzing catch curves (Beverton and Holt, 1957) based on fully recruited age fish and older. If the $\log_e$ of the age frequency in the catch is plotted on age, the slope of the descending right limb of the curve is equal to the mean instantaneous rate of total annual mortality (Z) assuming constant recruitment and survival (Everhardt and Youngs, 1981). To calculate mortality rates for different fishing areas and gears for males, females, and sexes combined we constructed three age-length keys (i.e. the distribution of ages at 50 mm FL intervals) following Ricker (1975): One for both sexes combined, one for females, and one for males. Age-length keys were then applied as appropriate to randomly collected length frequency data for specific areas, gears and sexes.

Results and Discussion

Age

Whole otoliths were excellent for aging king mackerel. Rings were usually distinct and easily counted and measured. We selected whole otoliths since they were easier to prepare than sections, and because Johnson et al. (1983) found little difference in ages determined from sections with those obtained by reading whole structures. They compared age estimations based on sectional and surface readings of fish 0+ to 14+ years old and found 96.5 percent agreement. We conducted our own test by counting rings on sections and on whole otoliths from the same fish. Readings of age structures from 24 of the larger fish (950-1250 mm FL) revealed 87 percent agreement. Of the 1,098 whole otoliths we examined, 89.7 percent (985) could be aged, and 86.2 percent (947) were legible enough to record measurements for back calculations. Most of those not legible had been either stored in glycerin or left in fish that had rotted due to electric freezer failure. Some of the latter otoliths were salvaged, however, by soaking them in ethanol prior to immersing them in clove oil. Legibility of this group improved from less than 20 percent to >60 percent by using this procedure.

The usefulness of any hard structure to estimate fish age should first be proven. Critical to this decision is that there must be a positive relationship between the size of the fish and the size of the structure, and age marks must be periodically formed and consistently located on the hard part. Four observations support the use of whole otoliths for aging king mackerel and validate rings as annual marks. First, the mean lengths of fish progressively increased as the number of rings (age) increased. Second, there was a strong correlation between otolith radii and fish lengths ($r = 0.97$). Third, marginal increment analyses and plots of percentages of otoliths with marginal rings by month, generally showed a peak in ring formation from February through May (Fig. 1). And last, plots of the focus-to-ring measurement revealed a single mode for each ring, consistent specific ring location for different age groups (Fig. 2, 3), and the modes had increasing overlap with age. This is the first report in which all of these conditions have been satisfied for king mackerel. Beaumariage (1973) and Johnson et al. (1983) also studied the age and growth of the species in the Gulf of Mexico, but their marginal increment analy-

[3]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

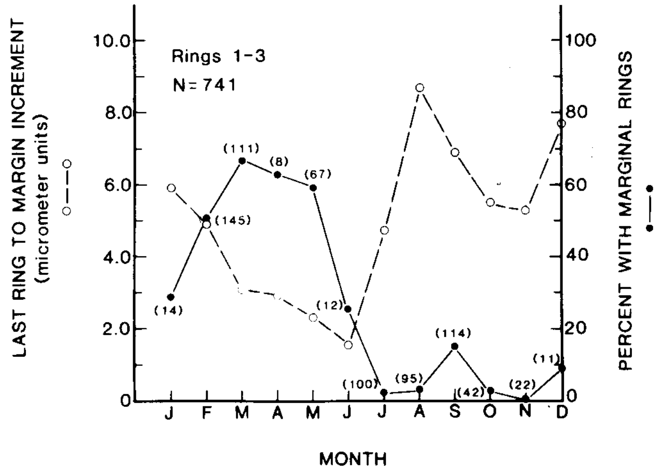

Figure 1.—Distance from the last ring to the otolith margin, and percentage of otoliths with marginal rings, by month, for fish with 1-3 rings.

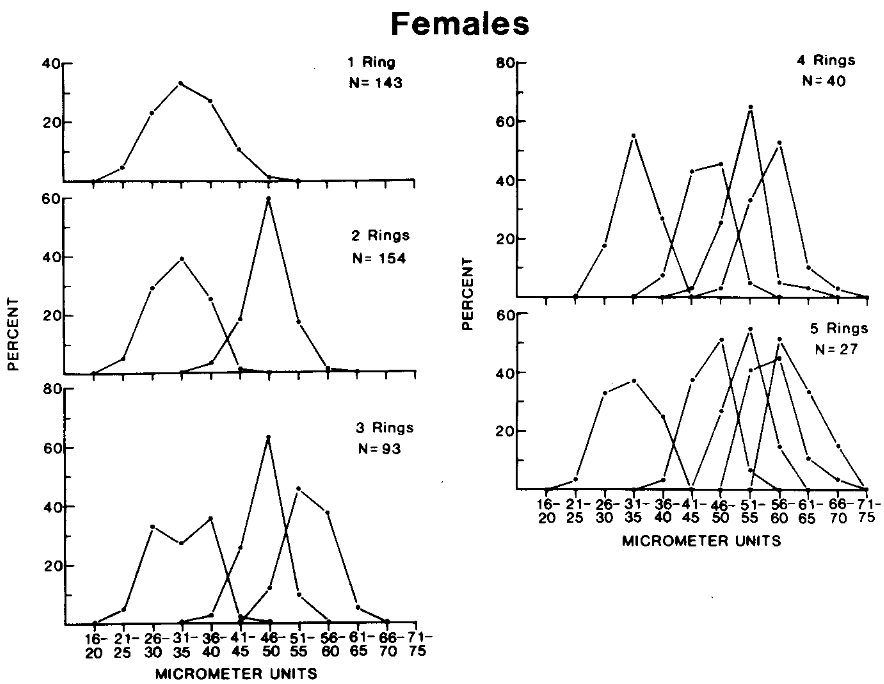

Figure 2.—Otolith focus-to-ring measurements for female king mackerel aged 1-5 years.

ses were not as conclusive. Beaumariage suggested ring formation in April, May, and June, and Johnson et al. reported May as the month when most rings were deposited. However, both studies included little or no data for the months of reported ring formation.

About 77 percent of the 985 fish we aged were ages 1-3 (26.8 percent age 1, 34.4 percent age 2, and 15.6 percent age 3). Johnson et al. (1983) found 70.21 percent of the fish to be 1-3 years old, excluding Louisiana samples. In both studies, females dominated age groups older than age 6. About 90 percent of our fish 1,000 mm FL or larger were females.

Back-Calculated Growth

Lengths at age were back calculated using three otolith radius-fish length regressions:

$FL = 7.002\ OR^{1.674}$, N = 210, r = 0.970 for both sexes combined,
$FL = 6.745\ OR^{1.1778}$, N = 122, r = 0.966 for females, and
$FL = 7.835\ OR^{1.1369}$, N = 88, r = 0.968 for males.

By substituting the means of the distance from the core to each annulus for OR in the above equations, we calculated the mean fish length at the time of each annulus formation, and the mean annual growth increment at each age for all fish, and by sex (Tables 2-4).

Growth in length was relatively fast for the first 3 years of life, but declined thereafter, and substantial annual growth was evident through age 14 (Table 2). Annual increments for the first 3 years for males and females combined were 420, 206, and 97 mm, respectively, and fell to only 34 mm at age 14. Annual increments for females were greater than for males (Tables 3, 4). Johnson et al (1983) found annual increments for the first 3 years for females to be 434, 218, and 95 mm, whereas ours were 425, 210, and 103 mm. Their increments for males were 414, 199, and 76 mm compared with 415, 199, and 84 mm for our samples. Thus, age and growth results between these two studies were almost identical for the age groups comprising the bulk of the fishery.

To analyze the similarity of these studies further, we compared data from Johnson et al. (1983) (Tables 7, 8) with our Tables 3 and 4 (Fig. 4, 5). Sample sizes in both studies are substantial for females aged 1-7 years and for males aged 1-6 years. Age and growth results are very similar for these age groups. In fact, for ages 1-5, which include 90-94 percent of all fish aged, the mean back-calculated lengths are almost identical (Fig. 4, 5). As females exceed aged 7 and males exceed age 6, mean-lengths at age become progressively dissimilar. The differences in Johnson, et al. (1983) and our lengths at age for older fish may be primarily attributable to small sample sizes in those age groups in the former study. We conclude that our lengths for older fish better represent growth in later life for the species because we have larger sample sizes in those age groups. Beaumariage (1973) reported much larger mean back-calculated lengths for ages 1-3 for king mackerel in Florida, but his reported lengths for older fish were more similar to ours than to that of Johnson et al. (1983) (Table 5). The Beaumariage (1973) data were converted from standard lengths to fork lengths for this comparison.

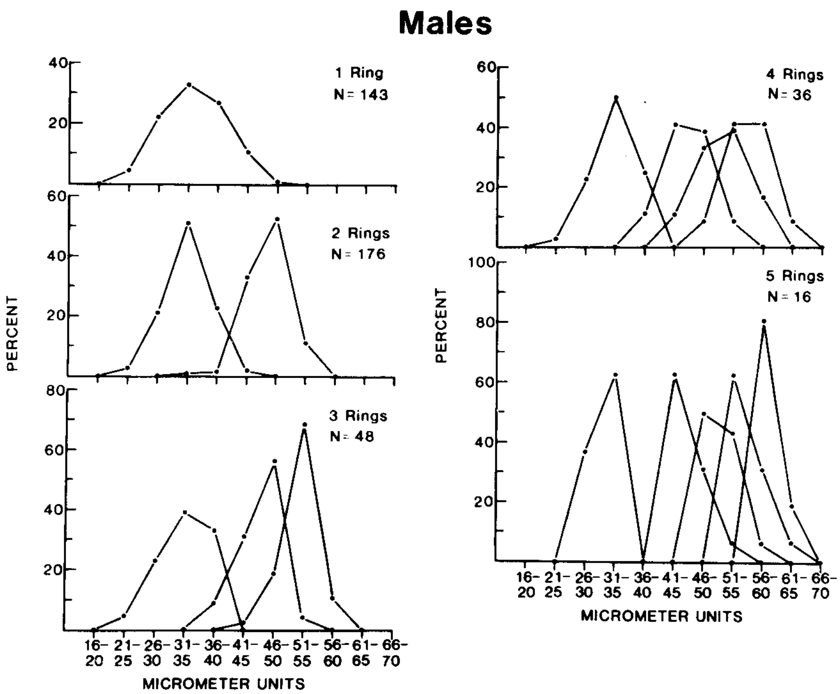

Figure 3.—Otolith focus-to-ring measurements for male king mackerel aged 1-5 years.

Theoretical Growth

Theoretical growth models provide growth parameters such as asymptotic size (L_∞), and growth coefficient (K) that may be used in constructing dynamic pool yield models. The most frequently used curve is the von Bertalanffy equation: $L_t = L_\infty(1 - e^{-K(t-t_0)})$, where L_t = length at age t (usually in years), and t_0 = time when fish are 0 length according to the fitted curve. The curve was fitted to back-calculated lengths (Everhart et al., 1975; Ricker, 1975) using Marquardt's nonlinear iterative procedure, and growth parameter estimates with 95 percent asymptotic confidence intervals (C.I.) were obtained for all fish, for females, and for males (Table 6):

$L_t = 1{,}478\ (1 - e^{-0.1154(t + 2.3599)})$ for both sexes combined,

$L_t = 1{,}417\ (1 - e^{-0.1360(t + 0.9754)})$ for females, and

$L_t = 1{,}113\ (1 - e^{-0.2080(t + 1.4808)})$ for males.

We also derived growth parameters for females aged 1-10 years and for males aged 1-9 years so that the parameters could be compared with Johnson et al. (1983), who used similar data (i.e. younger fish) to derive their models. Even with restricted ages, our models predicted larger fish for older age groups.

Theoretical fitted growth parameters for females and males and back calcu-

Table 2.—Average back-calculated fork lengths (mm) at age for king mackerel from all areas, 1980-85.

		Age in years													
Age	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	261	418.3													
2	336	417.4	631.6												
3	145	420.6	627.9	740.0											
4	77	425.8	608.8	701.8	774.2										
5	44	408.6	619.5	714.5	779.5	836.0									
6	28	422.8	614.7	712.3	783.0	844.8	893.7								
7	20	440.7	631.6	722.1	791.7	852.4	903.9	945.1							
8	10	432.6	600.6	707.1	782.1	850.0	897.4	945.1	981.5						
9	14	439.1	621.3	716.7	793.3	857.0	910.6	967.2	1,010.0	1,050.6					
10	5	432.6	636.3	734.1	811.1	869.5	935.2	984.8	1,034.9	1,075.1	1,112.2				
11	4	418.6	584.3	749.2	833.8	903.1	960.8	1,002.3	1,039.9	1,081.9	1,115.6	1,149.5			
12	2	444.4	658.2	737.3	817.6	882.6	940.1	998.1	1,039.9	1,081.9	1,132.5	1,166.5	1,209.2		
13															
14	1	400.3	565.1	673.9	737.3	801.4	866.3	915.4	998.1	1,048.3	1,098.7	1,149.5	1,200.6	1,234.9	1,269.3
Number		947	686	350	205	128	84	56	36	26	12	7	3	1	1
Weighted means		419.7	625.9	723.1	782.2	847.7	905.8	959.6	1,010.2	1,062.4	1,115.6	1,154.4	1,206.3	1,234.9	1,269.3
Annual increment		419.7	206.2	97.2	59.1	65.5	58.1	53.8	50.6	52.2	53.2	38.8	51.9	28.6	34.4

Table 3.—Average back-calculated fork lengths (mm) at age for female king mackerel from all areas, 1980-85.

		Age in years													
Age	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	143	436.0													
2	154	413.3	642.5												
3	93	422.0	637.6	756.8											
4	39	428.1	614.5	712.6	789.0										
5	27	413.9	623.9	723.0	792.1	850.3									
6	16	417.3	624.7	724.2	797.1	861.8	910.6								
7	11	472.9	654.5	741.7	817.2	878.5	936.1	980.5							
8	8	438.7	601.1	714.2	795.2	865.0	914.8	962.8	1,000.7						
9	8	447.9	640.4	734.3	817.6	883.5	939.8	1,000.7	1,045.3	1,092.2					
10	4	429.3	644.4	744.3	825.8	883.5	950.2	1,004.9	1,055.9	1,098.6	1,137.2				
11	3	409.6	581.6	772.7	865.6	932.1	993.6	1,038.8	1,078.5	1,118.6	1,153.1	1,187.7			
12	2	444.4	658.2	737.3	817.6	882.6	940.1	998.1	1,039.9	1,081.9	1,132.5	1,166.5	1,209.2		
13															
14	1	400.3	565.1	673.9	737.3	801.4	866.3	915.4	998.1	1,048.3	1,098.7	1,149.5	1,200.6	1,234.9	1,269.3
Number		509	366	212	119	80	53	37	26	18	10	6	3	1	1
Weighted means		425.0	634.9	738.1	799.0	866.2	928.9	987.6	1,034.8	1,094.4	1,137.2	1,174.3	1,206.3	1,234.9	1,269.3
Annual increments		425.0	209.9	103.2	60.9	67.2	62.7	58.7	47.2	59.6	42.8	37.1	32.0	28.6	34.4

Table 4.—Average back-calculated fork lengths (mm) at age for male king mackerel from all areas, 1980-85.

		Age in years										
Age	N	1	2	3	4	5	6	7	8	9	10	11
1	110	395.9										
2	176	423.0	620.3									
3	48	420.6	609.6	709.7								
4	36	424.9	603.3	687.9	756.5							
5	16	406.5	609.6	695.0	751.7	803.0						
6	12	431.7	601.2	694.7	761.3	818.3	866.5					
7	8	406.5	612.5	699.8	759.4	813.7	856.7	894.0				
8	2	410.1	601.2	684.5	738.2	800.1	839.0	886.1	917.7			
9	6	429.2	596.3	692.1	758.7	818.3	867.7	917.7	957.3	989.1		
10	1	446.2	608.7	699.8	761.3	823.4	886.1	917.7	965.2	997.1	1,029.1	
11	1	446.2	593.7	684.5	745.9	823.4	870.4	901.9	933.5	981.1	1,013.1	1,045.1
Number		416	306	130	82	46	30	18	10	8	2	1
Weighted means		415.2	614.4	698.4	756.2	811.6	863.1	902.8	947.8	989.1	1,021.1	1,045.1
Annual increment		415.2	199.2	84.0	57.8	55.4	51.5	39.7	45.0	41.3	32.0	24.0

Table 5.—Back-calculated lengths at ages for king mackerel from three different studies.

	Females			Males		
Age	This study	Beaumariage	Johnson et al.	This study	Beaumariage	Johnson et al.
1	425	491	434	415	457	414
2	635	703	652	614	643	613
3	738	793	747	698	705	689
4	799	857	807	756	752	734
5	866	928	854	812	795	777
6	929	986	899	863	822	809
7	988	1,033	939	903	839	851
8	1,035			948		
9	1,094			989		
10	1,137			1,021		
11	1,174			1,045		
12	1,201					
13	1,235					
14	1,269					

Table 6.—Theoretical growth parameters for different sex and age categories.

	Parameters					
Category	L_∞	95% C.I.	K	95% C.I.	t_0	95% C.I.
All sexes, all ages	1,478	1,316-1,640	0.1154	0.0791-0.1517	−2.3599	−1.4367-3.2831
Females, ages 1-14	1,417	1,310-1,524	0.1360	0.1030-0.1690	−1.9754	−1.2718-2.6790
Males, ages 1-11	1,113	1,027-1,199	0.2080	0.1442-0.2718	−1.4808	−0.7224-2.2392
Females, ages 1-10	1,298	1,120-1,476	0.1719	0.0999-0.2439	−1.5481	−0.6404-2.4558
Males, ages 1-9	1,044	950-1,138	0.2578	0.1638-0.3518	−1.1198	−0.3731-1.8664

lated lengths at age for our study and for four others are given in Tables 7 and 8. Our estimated lengths at age for females appear most similar to those obtained by Ximenes et al. (1978) and Johnson et al. (1983) (Table 8).

Mortality and Age of Recruitment

The problems of obtaining reliable

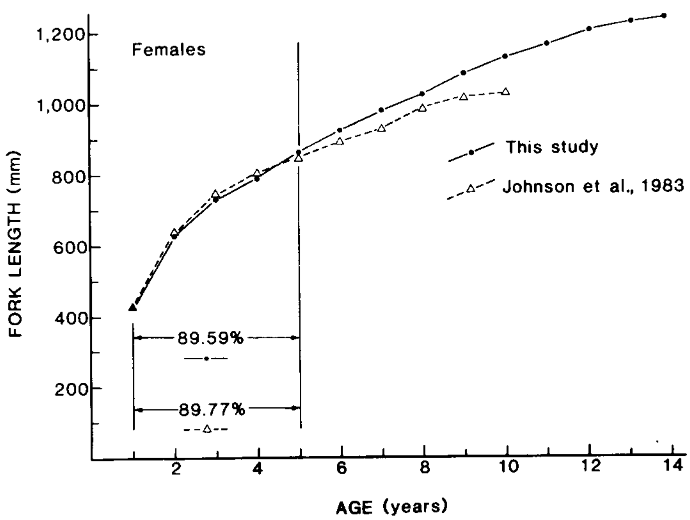

Figure 4.—Back-calculated mean FL (mm) at ages for female king mackerel from this study and from Johnson et al. (1983).

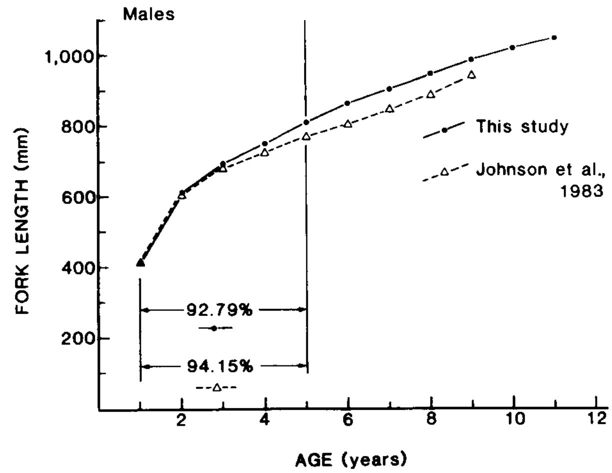

Figure 5.—Back-calculated mean FL (mm) at ages for male king mackerel from this study and from Johnson et al. (1983).

Table 7.—Theoretical growth parameters for king mackerel obtained from different studies. An asterisk (*) indicate parameter values that fall outside our asymptotic 95 percent confidence intervals for parameter estimates for females ages 1-14 and males ages 1-11 (Table 6).

Sex and source	L_∞ (mm FL)	K	t_0 (years)
Females			
This study	1,417	0.136	−1.98
Johnson et al. (1983)	1,067*	0.290*	−0.97
Ximenes et al. (1978)	1,317	0.164	−2.00[1]
Beaumariage (1973)	1,243	0.210	−2.40
Nomura and Rodriques (1967)	1,370	0.150	−0.13
Males			
This study	1,113	0.208	−1.48
Johnson et al. (1983)	965*	0.280	−1.17
Ximenes et al. (1978)	1,133	0.229	−1.50[1]
Beaumariage (1973)	903*	0.350	−2.50
Nomura and Rodriques (1967)	1,160	0.180	−0.22

[1]Assume negative.

mortality estimates for king mackerel are underscored by the fact that the species is highly migratory, schools by size (and perhaps by sex), is exploited by a variety of fishing gear having different selectivity characteristics, and one sex lives longer and attains larger sizes than the other. Mortality estimates derived from catch curves for king mackerel may be considered only general approximations because they may be biased by gear selectivity, such as gill nets, or the availability of certain sized individuals to fisheries over any given period of time. In addition, the principal assumptions of constant recruitment and survival may be questionable, because from 1980 to 1985 recruitment may have been declining and fishing mortality was certainly increasing (Scott and Burn[4],). To minimize these methodological problems we analyzed catch curve data for different fishing gear, different areas, and over different time intervals. We assumed that recreational hook-and-line data provided the best estimates of total instantaneous mortality, because only the very small fish would be excluded from the catch, and because angler catch and effort would best represent the ages of mackerel caught from many schools on many separate occasions.

Mortality estimates show considerable variation among years, gear types and areas (Table 9). Length frequency data from Trent et al.[5] were used to construct catch curves and estimate mortality. Ages when the species are fully recruited vary from age 1 to age 3 depending on fishing gear or area. Gill nets operating

Table 8.—Theoretical lengths at ages for king mackerel from five different studies.

	Females					Males				
Age	This study	Johnson et al. (1983)	Beau-mariage (1973)	Nomura, Rodriques (1967)	Ximenes, et al. (1978)	This study	Johnson et al. (1983)	Beau-mariage (1973)	Nomura, Rodriques (1967)	Ximenes, et al. (1978)
1	471.6	464.4	634.3	213.6	511.8	448.7	439.4	637.7	228.8	493.9
2	591.8	616.1	749.7	374.7	633.6	573.4	567.8	716.1	382.1	624.6
3	696.7	729.6	843.0	513.3	737.0	674.8	664.8	771.3	510.3	728.7
4	788.3	814.5	918.8	632.7	824.7	757.1	738.1	810.2	617.2	811.5
5	868.3	878.0	980.2	735.4	899.1	823.9	793.5	837.6	706.7	877.3
6	938.0	925.6	1,029.9	823.8	962.3	878.2	835.4	856.9	781.4	929.6
7	999.0	961.6	1,070.3	899.8	1,015.9	922.3	867.1	870.5	843.8	971.3
8	1,052.1	987.8	1,103.0	965.3	1,062.0	958.2	891.0	880.2	895.9	1,004.3
9	1,098.5	1,007.8	1,129.5	1,021.7	1,100.2	987.3	907.1	886.4	939.4	1,030.7
10	1,139.0	1,022.7	1,151.0	1,070.2	1,133.0	1,010.9		891.6	975.7	1,051.7
11	1,174.4		1,168.4	1,112.0	1,160.8	1,030.1			1,006.1	1,068.3
12	1,205.3		1,182.6	1,147.9	1,184.4					
13	1,232.2		1,194.0	1,178.9	1,204.5					
14	1,255.7		1,203.0	1,205.5	1,221.5					

[4]Scott, G. P., and D. M. Burn. 1987. Updated assessment information on the king mackerel resource in the southeastern United States. Miami Laboratory, NMFS Southeast Fisheries Center, Coastal Resources Div., Contr. ML-CRD-86/87-18. Unpubl. rep.

[5]Trent, L., M. Godcharles, B. J. Palko, L. A. Collins, and L. A. Trimble. Lengths of king mackerel, *Scomberomorus cavalla*, in the southeastern United States by area, capture, gear, year, month, and sex, 1968-1984. Panama City Laboratory, Southeast Fisheries Center, NMFS, NOAA, Panama City, Fla. Unpubl. manuscr.

Table 9.—Total instantaneous mortality estimates (Z) for king mackerel from three areas in the Gulf of Mexico.

Area and year	Sex	Gear[1]	Recruitment age	Z	r	N
S. Fla.						
1980	U	GN	2	−0.53	−0.98	1,600
1981	M	GN	2	−0.82	−0.96	1,845
1981	F	GN	2	−0.63	−0.99	1,117
1981	Tot.	GN	2	−0.72	−0.99	2,962
1984	M	GN	2	−0.73	−0.96	1,261
1984	F	GN	2	−0.60	−0.99	1,577
1984	Tot.	PS	2	−0.50	−0.99	192
N.W. Fla.						
1980	Tot.	RHL	1	−0.54	−0.95	6,732
1980	M	RHL	2	−1.01	−0.95	316
1980	F	RHL	1	−0.46	−0.90	531
Texas						
1980	M	RHL	2	−0.47	−0.95	314
1980	F	RHL	3	−0.29	−0.90	301
1980	Tot.	RHL	2	−0.42	−0.95	731

[1]GN = gill net, PS = purse seine, RHL = recreational hook and line.

off south Florida always recruited age 2 fish, whereas recreational hook and line caught mackerel were recruited at age 1 and age 2 off northwest Florida, and at age 2 and age 3 off Texas (Table 9). Although varying by gear and area, mortality estimates for males were always greater than for females. Values were lowest for recreational hook-and-line (RHL) fish off Texas ($Z = 0.29$-0.47), intermediate for RHL caught fish off northwest Florida ($Z = 0.46$-1.01), and highest for king mackerel captured by gill nets off south Florida ($Z = 0.53$-0.82). Although the catch-curve method provides approximate mortality estimates, our results are apparently robust in that they show a generally increasing trend in total mortality with time. Our results agree with Scott and Burn[4] who report increasing fishing mortality during these same years from an age-structured analysis (virtual population analysis).

Summary

Our data indicate that rings on otoliths of king mackerel are formed annually on most fish during the late winter and spring. There is also an apparent ring deposition during September for some fish captured off northwest Florida. The otoliths from this group represented only a small fraction of the total number of otoliths we examined. Fall ring formation is yet unexplained, but may be representative of a separate spawning group.

The dominant age groups of king mackerel caught throughout the Gulf of Mexico were ages 1-3. In catch curves derived for fish collected off Key West, Fl., northwest Florida, and Texas, percentages of age groups 1-3 ranged from 42.5 to 94.9 (weighted mean = 78.0 percent; 17,457 of 22,375 fish). Fish aged 4-7 years were also relatively common, and those older than age 7 were rare. Our study and that by Johnson et al. (1983) adequately describe the growth of king mackerel aged 1-7 years, the age groups that actually support commercial and recreational fisheries in the Gulf of Mexico. For older fish, our data and those of Ximenes et al. (1978) may be the best representation of growth. Because our data were more complete (i.e., larger sample size at older ages) and we used more exact (iterative) curve fitting procedures than earlier studies, our theoretical growth parameters represent an important data set and consideration should be given to using them to derive population models for king mackerel in the Gulf of Mexico.

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